

WHAT IS CLAIMED IS:

1                   1.       A reactor for growing a gallium containing single crystal,  
2   comprising:  
3                   a first growth zone;  
4                   means for heating at least one substrate within said first growth zone to a  
5   first temperature, wherein said first temperature is greater than 850 °C;  
6                   a gallium source zone;  
7                   means for heating a first portion of a gallium source within said gallium  
8   source zone to a second temperature, wherein said second temperature is greater than 450  
9   °C;  
10                  means for heating a second portion of said gallium source within said  
11   gallium source zone to a third temperature, wherein said third temperature is greater than  
12   30 °C, and wherein said third temperature is less than 100 °C;  
13                  a halide reaction gas source coupled to said gallium source zone;  
14                  an inert gas source coupled to said gallium source zone to transport a first  
15   reaction product from said gallium source zone to said first growth zone; and  
16                  a reaction gas source coupled to said first growth zone.

1                   2.       The reactor of claim 1, further comprising:  
2                   a first aluminum source zone, wherein said halide reaction gas source is  
3   coupled to said first aluminum source zone, and wherein said inert gas source is coupled  
4   to said first aluminum source zone; and  
5                   means for heating a first aluminum source within said first aluminum  
6   source zone to a fourth temperature, wherein said fourth temperature is greater than 700  
7   °C.

1                   3.       The reactor of claim 2, further comprising:  
2                   a second aluminum source zone, wherein said halide reaction gas source is  
3   coupled to said second aluminum source zone, and wherein said inert gas source is  
4   coupled to said second aluminum source zone; and  
5                   means for heating a second aluminum source within said second aluminum  
6   source zone to a fifth temperature, wherein said fifth temperature is greater than 700 °C.

1                   4.       The reactor of claim 3, further comprising means for alternately  
2 coupling said first and second aluminum source zones to said halide reaction gas source  
3 and said inert gas source, wherein said means for heating said first aluminum source and  
4 said means for heating said second aluminum source are the same heating means, and  
5 wherein said heating means alternates between heating said first aluminum source and  
6 said second aluminum source.

1                   5.       The reactor of claim 1, wherein said means for heating said first  
2 growth zone, said first portion of said gallium source, and said second portion of said  
3 gallium source is a multi-zone resistive heater furnace.

1                   6.       The reactor of claim 2, wherein said means for heating said first  
2 growth zone, said first portion of said gallium source, said second portion of said gallium  
3 source, and said first aluminum source is a multi-zone resistive heater furnace.

1                   7.       The reactor of claim 1, further comprising:  
2 an acceptor impurity source zone, wherein said inert gas source is coupled  
3 to said acceptor impurity source zone; and  
4 means for heating an acceptor impurity within said acceptor impurity  
5 source zone to a fourth temperature.

1                   8.       The reactor of claim 1, further comprising:  
2 a donor impurity source zone, wherein said inert gas source is coupled to  
3 said donor impurity source zone; and  
4 means for heating a donor impurity within said donor impurity source zone  
5 to a fourth temperature.

1                   9.       The reactor of claim 1, further comprising means for transferring  
2 said at least one substrate within said first growth zone to a second growth zone.

1                   10.      The reactor of claim 9, further comprising means for heating said at  
2 least one substrate within said second growth zone to a fourth temperature.

1                   11.      The reactor of claim 10, wherein said first temperature is within a  
2 range of 1,000 °C to 1,100 °C and wherein said fourth temperature is within a range of  
3 850 °C to 1,000 °C.

12. A reactor for growing a gallium containing single crystal,  
 comprising:  
 a multi-zone heater at least partially surrounding at least a portion of the  
 reactor;  
 a first growth zone, wherein said multi-zone heater heats any substrates  
 held within said first growth zone to a first temperature in the temperature range of 1,000  
 °C to 1,100 °C;  
 a second growth zone, wherein said multi-zone heater heats any substrates  
 held within said second growth zone to a second temperature in the temperature range of  
 850 °C to 1,000 °C;  
 a multi-temperature gallium source zone, wherein said multi-zone heater  
 heats a first portion of a gallium source within said multi-temperature gallium source  
 zone to a third temperature greater than 450 °C, and wherein said multi-zone heater heats  
 a second portion of said gallium source within said multi-temperature gallium source  
 zone to a fourth temperature greater than 30 °C and less than 100 °C;  
 an HCl gas source coupled to said multi-temperature gallium source zone,  
 wherein a reaction between an HCl gas supplied by said HCl gas source to said multi-  
 temperature gallium source zone and said first portion of said gallium source forms a  
 gallium chloride reaction product;  
 an inert gas source coupled to said multi-temperature gallium source zone,  
 wherein an inert gas supplied by said inert gas source to said multi-temperature gallium  
 source zone transports said gallium chloride reaction product from said multi-temperature  
 gallium source zone to said first and second growth zones;  
 an ammonia gas source coupled to said first and second growth zones,  
 wherein a reaction between an ammonia gas supplied by said ammonia gas source to said  
 first and second growth zones and said gallium chloride reaction product forms a first  
 portion of said gallium containing single crystal; and  
 means for transporting said at least one substrate between said first growth  
 zone and said second growth zone, wherein a reaction between said ammonia gas  
 supplied by said ammonia gas source to said second growth zone and said gallium  
 chloride reaction product forms a second portion of said gallium containing single crystal.

13. The reactor of claim 12, said multi-zone heater further comprising at least one resistive heater.

14. The reactor of claim 12, wherein said transporting means is a manually operating substrate positioning system.

15. The reactor of claim 12, wherein said transporting means is an automatic substrate positioning system.

16. The reactor of claim 12, further comprising a first aluminum source zone, wherein said multi-zone heater heats a first aluminum source within said first aluminum source zone to a fifth temperature greater than 700 °C, wherein said HCl gas source is coupled to said first aluminum source zone, wherein a reaction between said HCl gas supplied by said HCl gas source to said first aluminum source zone and said first aluminum source forms a first aluminum trichloride reaction product, wherein said inert gas source is coupled to said first aluminum source zone, wherein said inert gas supplied by said inert gas source to said first aluminum source zone transports said first aluminum trichloride reaction product from said first aluminum source zone to said first and second growth zones, and wherein a reaction between said ammonia gas supplied by said ammonia gas source to said first and second growth zones and said gallium chloride reaction product and said first aluminum trichloride reaction product forms said first portion of said gallium containing single crystal, said gallium containing single crystal containing aluminum.

17. The reactor of claim 16, further comprising a second aluminum source zone, wherein said multi-zone heater heats a second aluminum source within said second aluminum source zone to a sixth temperature greater than 700 °C, wherein said HCl gas source is coupled to said second aluminum source zone, wherein a reaction between said HCl gas supplied by said HCl gas source to said second aluminum source zone and second first aluminum source forms a second aluminum trichloride reaction product, wherein said inert gas source is coupled to said second aluminum source zone, wherein said inert gas supplied by said inert gas source to said second aluminum source zone transports said second aluminum trichloride reaction product from said second aluminum source zone to said first and second growth zones, and wherein a reaction between said ammonia gas supplied by said ammonia gas source to said first and second

12 growth zones and said gallium chloride reaction product and said second aluminum  
13 trichloride reaction product forms said first portion of said gallium containing single  
14 crystal, said gallium containing single crystal containing aluminum.

1 18. The reactor of claim 12, further comprising an acceptor impurity  
2 zone, wherein said multi-zone heater heats an acceptor impurity within said acceptor  
3 impurity zone to a fifth temperature, wherein said inert gas source is coupled to said  
4 acceptor impurity zone, wherein said inert gas supplied by said inert gas source to said  
5 acceptor impurity zone transports said acceptor impurity from said acceptor impurity  
6 zone to said first and second growth zones, wherein said gallium containing single crystal  
7 contains said acceptor impurity.

1 19. The reactor of claim 12, further comprising a donor impurity zone,  
2 wherein said multi-zone heater heats a donor impurity within said donor impurity zone to  
3 a fifth temperature, wherein said inert gas source is coupled to said donor impurity zone,  
4 wherein said inert gas supplied by said inert gas source to said donor impurity zone  
5 transports said donor impurity from said donor impurity zone to said first and second  
6 growth zones, wherein said gallium containing single crystal contains said donor  
7 impurity.

1 20. A reactor for growing a gallium containing single crystal,  
2 comprising:  
3 a multi-zone heater at least partially surrounding at least a portion of the  
4 reactor;  
5 a growth zone, wherein said multi-zone heater heats any substrates held  
6 within said growth zone to a first temperature greater than 850 °C;  
7 a multi-temperature gallium source zone, wherein said multi-zone heater  
8 heats a first portion of a gallium source within said multi-temperature gallium source  
9 zone to a second temperature greater than 450 °C, and wherein said multi-zone heater  
10 heats a second portion of said gallium source within said multi-temperature gallium  
11 source zone to a third temperature greater than 30 °C and less than 100 °C;  
12 an HCl gas source coupled to said multi-temperature gallium source zone,  
13 wherein a reaction between an HCl gas supplied by said HCl gas source to said multi-  
14 temperature gallium source zone and said first portion of said gallium source forms a  
15 gallium chloride reaction product;

an inert gas source coupled to said multi-temperature gallium source zone, wherein an inert gas supplied by said inert gas source to said multi-temperature gallium source zone transports said gallium chloride reaction product from said multi-temperature gallium source zone to said growth zone; and

an ammonia gas source coupled to said growth zone, wherein a reaction between an ammonia gas supplied by said ammonia gas source to said growth zone and said gallium chloride reaction product forms a first portion of said gallium containing single crystal.

21. The reactor of claim 20, wherein said multi-zone heater heats any substrates held within said growth zone to a fourth temperature in the temperature range of 1,000 °C to 1,100 °C for a first period of time, and wherein said multi-zone heater heats any substrates held within said growth zone to a fifth temperature in the temperature range of 850 °C to 1,000 °C for a second period of time.

22. The reactor of claim 20, further comprising a first aluminum source zone, wherein said multi-zone heater heats a first aluminum source within said first aluminum source zone to a fourth temperature greater than 700 °C, wherein said HCl gas source is coupled to said first aluminum source zone, wherein a reaction between said HCl gas supplied by said HCl gas source to said first aluminum source zone and said first aluminum source forms a first aluminum trichloride reaction product, wherein said inert gas source is coupled to said first aluminum source zone, wherein said inert gas supplied by said inert gas source to said first aluminum source zone transports said first aluminum trichloride reaction product from said first aluminum source zone to said growth zone, and wherein a reaction between said ammonia gas supplied by said ammonia gas source to said growth zone and said gallium chloride reaction product and said first aluminum trichloride reaction product forms said first portion of said gallium containing single crystal, said gallium containing single crystal containing aluminum.

23. The reactor of claim 22, further comprising a second aluminum source zone, wherein said multi-zone heater heats a second aluminum source within said second aluminum source zone to a fifth temperature greater than 700 °C, wherein said HCl gas source is coupled to said second aluminum source zone, wherein a reaction between said HCl gas supplied by said HCl gas source to said second aluminum source zone and second first aluminum source forms a second aluminum trichloride reaction

product, wherein said inert gas source is coupled to said second aluminum source zone, wherein said inert gas supplied by said inert gas source to said second aluminum source zone transports said second aluminum trichloride reaction product from said second aluminum source zone to said growth zone, and wherein a reaction between said ammonia gas supplied by said ammonia gas source to said first and second growth zones and said gallium chloride reaction product and said second aluminum trichloride reaction product forms said first portion of said gallium containing single crystal, said gallium containing single crystal containing aluminum.

24. The reactor of claim 20, further comprising an acceptor impurity zone, wherein said multi-zone heater heats an acceptor impurity within said acceptor impurity zone to a fourth temperature, wherein said inert gas source is coupled to said acceptor impurity zone, wherein said inert gas supplied by said inert gas source to said acceptor impurity zone transports said acceptor impurity from said acceptor impurity zone to said growth zone, wherein said gallium containing single crystal contains said acceptor impurity.

25. The reactor of claim 20, further comprising a donor impurity zone, wherein said multi-zone heater heats a donor impurity within said donor impurity zone to a fourth temperature, wherein said inert gas source is coupled to said donor impurity zone, wherein said inert gas supplied by said inert gas source to said donor impurity zone transports said donor impurity from said donor impurity zone to said growth zone, wherein said gallium containing single crystal contains said donor impurity.

26. A reactor for growing a gallium containing single crystal, comprising:  
a multi-zone heater at least partially surrounding at least a portion of the reactor;  
a first growth zone, wherein said multi-zone heater heats any substrates held within said first growth zone to a first temperature in the temperature range of 1,000 °C to 1,100 °C;  
a second growth zone, wherein said multi-zone heater heats any substrates held within said second growth zone to a second temperature in the temperature range of 850 °C to 1,000 °C;

means for transporting a substrate between said first growth zone and said second growth zone;

a multi-temperature gallium source zone, wherein said multi-zone heater heats a first portion of a gallium source within said multi-temperature gallium source zone to a third temperature greater than 450 °C, and wherein said multi-zone heater heats a second portion of said gallium source within said multi-temperature gallium source zone to a fourth temperature greater than 30 °C and less than 100 °C;

a first aluminum source zone, wherein said multi-zone heater heats a first aluminum source within said first aluminum source zone to a fifth temperature greater than 700 °C;

a second aluminum source zone, wherein said multi-zone heater heats a second aluminum source within said second aluminum source zone to a sixth temperature greater than 700 °C;

means for selecting between said first and second aluminum source zones;

an HCl gas source coupled to said multi-temperature gallium source zone, said first aluminum source zone, and said second aluminum source zone, wherein a reaction between an HCl gas supplied by said HCl gas source to said multi-temperature gallium source zone and said first portion of said gallium source forms a gallium chloride reaction product, and wherein a reaction between said HCl gas supplied by said HCl gas source to said selected first or second aluminum source zone and said selected first or second aluminum source forms an aluminum trichloride reaction product;

an inert gas source coupled to said multi-temperature gallium source zone, said first aluminum source zone, and said second aluminum source zone, wherein an inert gas supplied by said inert gas source to said multi-temperature gallium source zone transports said gallium chloride reaction product from said multi-temperature gallium source zone to said first and second growth zones, and wherein said inert gas supplied by said inert gas source to said selected first or second aluminum source zone transports said aluminum trichloride reaction product to said first and second growth zones; and

an ammonia gas source coupled to said first and second growth zones, wherein a reaction between an ammonia gas supplied by said ammonia gas source to said first and second growth zones and said gallium chloride reaction product and said aluminum trichloride reaction product forms the gallium containing single crystal.



1                    27.     The reactor of claim 26, further comprising an acceptor impurity  
2     zone, wherein said multi-zone heater heats an acceptor impurity within said acceptor  
3     impurity zone to a seventh temperature, wherein said inert gas source is coupled to said  
4     acceptor impurity zone, wherein said inert gas supplied by said inert gas source to said  
5     acceptor impurity zone transports said acceptor impurity from said acceptor impurity  
6     zone to said first and second growth zones, wherein said gallium containing single crystal  
7     contains said acceptor impurity.

1                    28.     The reactor of claim 26, further comprising a donor impurity zone,  
2     wherein said multi-zone heater heats a donor impurity within said donor impurity zone to  
3     a seventh temperature, wherein said inert gas source is coupled to said donor impurity  
4     zone, wherein said inert gas supplied by said inert gas source to said donor impurity zone  
5     transports said donor impurity from said donor impurity zone to said first and second  
6     growth zones, wherein said gallium containing single crystal contains said donor  
7     impurity.